EVALUATION OF MANNED SPACECRAFT PRELAUNCH CHECKOUT PRESENT AND PROPOSED

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INTRODUCTION

During approximately the past 3 or 4 years, personnel at MSC have had the responsibility for implementing the ACE-S/C checkout system into the operational world of Apollo CSM/LM Checkout. Along with this responsibility has come the advantages of being directly involved with resolving daily operational problems, developing engineering design changes, and generally assessing the ACE-S/C systems ability to meet the CSM/LM checkout and test requirements. As the equipment operators (Contractor and NASA) became more familiar with the system operation, and as the test personnel became more aware of the actual S/C test requirements, more demands were and are being placed on what the ACE-S/C checkout system must accomplish. In certain uses it became necessary to make significant hardware modifications to satisfy these requirements. In other cases, a matter of operational procedures was sufficient, or as is now the usual case, software design changes were implemented to meet the requirements.

It has become apparent to us at MSC that the ACE system as now implemented cannot much longer continue to satisfy new requirements or satisfy expanding tasks of new S/C programs with the needs for test and evaluation becoming more extensive and sophisticated. With this sort of knowledge, it became further obvious that yesterday was the time to start the next generation system concept and design development. To that end, several individuals at MSC have become active over the past ten months.

It is the intent of this paper to introduce some of our past thinking and to present what we feel are some of the salient features of a next generation S/C checkout system. To accomplish this, the paper will begin with a basic system designation of the present ACE-S/C system, identify recognized ACE capabilities, outline some of the more pertinent requirements for a new system, present one of our evaluation tools, define a new system organization, and then discuss in some detail our present work activity and status.

ACCEPTANCE CHECKOUT EQUIPMENT (ACE-S/C) - TODAY

The ACE-S/C checkout station being utilized today at NR-Downey, GAEC-Bethpage, KSC and at MSC are basically configured as they were when installation started in July 1964. In the first part of this section we will define this configuration, giving a brief functional description and system operating specifications. The latter part of this section will concentrate on system assessment which will briefly describe system loading, operational capabilities and constraints.

SYSTEM DESCRIPTION

The ACE-S/C checkout system is organized basically into three functional areas. These are:

a. Computer facility
b. Control Room
c. Spacecraft Interface equipments

These areas are linked together through another area called the Signal Distribution Room which, for the purpose of this paper, will be considered a passive patch element.

CONFIGURATION

Computer Room -

Looking at the computer facility we have the digital processors consisting of two CDC 160 G Computers and peripherals, the PCM data acquisition hardware which is two Radiation 540 decoms, a computer room control console, digital transmission and receiving terminals, real time and count down time code translators, and a number of digital, analog, and event type recorders (magnetic tape and paper).

The two computers are for all intents functionally dedicated processors.

The one computer, referred to as uplink, accomplishes the man interface whereby manual requests for S/C stimuli are recognized. This causes pre-determined digital command words to be formatted and transmitted to the S/C system or GSE via the digital transmission link. Other functions performed by the uplink computer include:

a. Control call in of alternate test sequence loads.
b. Recording on digital tape special error messages derived from the Guidance and Navigation System.
c. Control over playback of special recorded data.
d. Performing S/C to L/V Checkout computer communications.

The second computer, referred to as downlink, accomplishes the function of processing the S/C and GSE response data which is provided by the PCM decoms. The purpose of the computer processing is:

a. Engineering conversion and formatting for display to test personnel.
b. Formatting of compressed raw data for digital tape recording.
c. Buffering out display data to CRT's and other special direct driven elements.
d. Control input of data from decom.
e. Supplying uplink computer with telemetry information to permit automatic sequencing.
f. Special AGC processing.
g. Other engineering functions such as "OR'd" events and barometric pressure monitoring.

The PCM data acquisition hardware performs the standard functions of PCM synchronization, word formatting, and providing display routing information. In addition, the basic hardware has been modified to permit:

a. Tolerance testing of parameters against fixed limits.
b. Tolerance testing of parameters against a floating limit (dynamic tolerance).
c. Direct access to computer memory for storing PCM data in specific memory locations.

The computer room control console provides necessary display information and controls to permit integration of the computer room activities with those activities being performed in the control room. Basically it contains:

a. CRT display for A/N data.
b. Status lights for computer room equipment performance.
c. Control devices for computer communications by the operator.
d. Controls over analog mag tape recorders.
e. Clock controls.

The digital transmission terminals provide for communicating with remote digital equipments. Its functions are to take parallel computer words, serializing the data and redundantly transmitting over hardlines. The terminals also receive serialized data from the remote digital equipments, checks for transmission errors, puts into parallel format for input to a computer.

The real time and count down time code translators are utilized to format standard IRIG timing signals into a computer compatible format and directly interfaces with both computers.

Recording of S/C test data is partially accomplished by the various recorders in the computer room. This includes the computer digital tapes used for recording of compressed raw S/C and GSE measurements, the analog mag tapes for recording raw PCM data, and paper strip charts recorders for analog and event type responses.

Control Room -

The control room is that area in the ACE-S/C system which provides the primary control over S/C testing. Configuration of the control room is a series of low-boy and high-boy consoles which are physically and functionally grouped into elements which normally relate to a S/C system. These consoles are then manned by appropriate systems test personnel. The task of integrating the activities at the system consoles is performed by S/C test conductors at their own console grouping. The system consoles are so designed to provide the necessary real time test information to the operator as well as providing the operators with the necessary controls for stimuli execution or S/C and GSE systems control. The basic console elements are:

a. Displays
b. Starts (computer input devices)
c. Recorders

The displays are composed of two types. Alphanumeric displays, which are computer (downlink) driven with real time processed engineering information, and decom or computer driven event lights and analog meter modules.

Three types of starts, C, R, and K, are used by operators to input control requests to the uplink computer which are then translated to stimuli signals to S/C and GSE systems. The C-STARTS provide for input of 10 BCD characters or plus/minus signs into the computer. C-STARTS are used normally to control analog voltage generations, operator message inputs, or can be used as a redundant back-up to the R-STARTS. The R-STARTS are four bit binary type input operator messages which are normally used for applying discrete voltage to systems or to control relays. The K-START is used exclusively for communicating with the S/C onboard computers. K-START data inputs, via paper tape or manual keyboard, consist of decimal characters or binary coded function words.

Recorders are mounted in the operator consoles and are driven either directly by the decom or can be driven by computer generated data. The recorders are standard 8 channel analog recorders and 100 channel event recorders under manual control. Time code recordings accompany the signal recordings on appropriate tracks.

Spacecraft Interface -

The S/C interface equipments are those digital units which provide the direct interface between the S/C or GSE, and the ACE-S/C computer room facility, or central control station. The interface equipment consists of the Digital Test Command System (DTCS) which is the stimuli source or uplink side, and the Digital Test Monitor System (DTMS) which provides the system outputs or response via the PCM or downlink data.

The DTCS receives coded serial messages from the uplink computer terminals, checks for transmission errors, decodes the message as to type, i.e., analog, relay, or digital computer word, routes and applies signal to the proper stimuli point. The DTMS performs two basic functions. It monitors S/C system and GSE outputs and encodes these into PCM, and secondly it functions to interleave or time multiplex up to four PCM trains into a single PCM stream. The interleaved signal is then transmitted over hardlines to the ACE-S/C decom system.

SYSTEM CAPABILITY

In performing the job of S/C checkout there exists certain functional tasks which the ACE-S/C system must be capable of satisfying. For instance, the ACE-S/C system must be capable of supplying the full stimuli spectrum required for checkout and at the same time handle the total PCM data stream. One of the biggest tasks is that of processing information and preparing it for presentation to the user; i.e., the test operator, so that he can make proper decisions about test continuance and control. The system is basically a two computer control system working together through a shared memory concept. The shared memory forms a type of data bank supplied with information by the decoms and buffered I/O devices directly accessing the shared memory. The processors are supported by real time and countdown clocks which can be pre-set to signal the processors at the proper time or interval. Through a series of interrupt levels, control of the processing tasks is accomplished by the processor executive. This part of the discussion will present system capability in terms of information flow rates and types of information outputs.

Downlink - Taking the S/C as the starting point, information is generated by three basic data sources. One source is the flight PCM which transfers information at 51.2/1.6 kbs and is the normal source for inflight information. A second source is 51.2 kbs data stream gathered from S/C GSE with the third source being a 51.2 kbs data stream which is generated by an external PCM generator connected to additional system measurement points required for checkout. The three data sources are then interleaved with a spare 51.2 link to form one continuous PCM data stream of 204 kbs. Each data stream contains the capacity for 128 time slots of 8 bit words, repetitively transmitted at 50 times per second. This then creates the basic real time process update rate of 20 milliseconds for the collective data stream of 512 available time slots. The PCM decoms perform the standard function of bit synch, prime frame synch and ID or subframe synchronization. The decom is a stored program processor which has the ability to directly route the 8-bit data words to analog meters or to event lights. Through the direct memory access mod, mentioned earlier, the decom sorts measurements by sample rate - 50, 10, 1 - and stores each of these in a unique address in computer memory (higher sample rates are treated as separate 50 sps measurements). Additionally, each measurement can be checked against fixed high/low limits, and against a floating limit which uses a fixed tolerance. Data stored in computer memory is, therefore, uniquely located and flagged as to result of limit checks.

The downlink computer now has the task of measurement handling, engineering conversions, formatting, and ground processing. One of its real time tasks is that of reviewing all measurements for a floating limit flag and processing them for recording on a digital tape (CDT - Compressed Data Tape). For 50 sps measurements or higher sample rates, the computer must cover these measurements every 20 milliseconds. The 10 sps measurements must be completely reviewed by every fifth frame while the 1 sps measurements must be checked only once every 50 frames. This task is of utmost importance in that the CDT has been identified as the prime source of data for post test processing and analysis. A second real time function of the downlink processor is that of getting information displayed to the operators in a meaningful manner. This involves engineering limit conversion, raw data translation with cal data, formatting, and alpha numeric scope updating. Except for selected measurements, scope updating is performed once per second. Special type display processing includes the performance of "logical ORing" of selected system outputs and displaying these on event type displays under computer control. Included within the special type of real time processing for display is the computer process of S/C computer(s) words with results being placed on the G/N CRT display and/or event type displays and recorders. A third basic real time process requirement is that of critical response detection. This is principally a

task of continuous monitoring of the PCM stream to detect the unspecifiable time of occurrence type signal. This signal may be an out-of-limit occurrence, a response to some stimulus input, or an unanticipated change in state of a steady state line which creates a critical or catastrophic response. Computer response to the occurrences range from signaling the uplink computer to proceed to the next test sequence such as in automatic test sequences, to displaying the occurrence on a CRT or event light and recording on a magnetic tape file.

The uplink computer becomes the next logical step around the S/C - checkout equipment loop. Its principal design function is to communicate with the S/C and GSE systems. Communications from man to computer is via the "START" (C, R, & K) function control panels. The ACE-S/C system utilizes one CUE (communications unit executor) to multiplex a maximum of 256 start address, i.e., positions from which commands can be generated. The multiplex or scan around rate of the CUE is approximately 20 milliseconds with priority response being given to the C-START type requests. To permit automatic computer generation of uplink commands and still retain the manual command features of "Start Verify" and command filing on magnetic tape, the computer performs a pseudo manual stimuli generation. This is accomplished by using a software program referred to as ADAP whereby actual START addresses are internally acknowledged by the computer with verification signals being transmitted to the STARTS and at the same time a recording on mag tape of the command and the address of where the stimuli was applied. Stimuli commands are formatted and buffered out over serial links to the S/C systems. The rate of data transmission is 1 mega bit/sec. To assure that possibility of erroneous transmissions are negligible, 100% redundant transmission techniques are utilized. Additionally, double command transmission with a comparison test is made prior to stimuli application. Due to these error checks and command word size which is 24 bits, the effective command execution rate approximates 1000 points per second. A coded message which identifies whether or not errors in transmission or decoding have occurred in the stimuli operation is returned to the uplink computer by the S/C interface equipment. Whereas relay activation or discrete voltage generation is the result of one complete command sequence, the analog voltage generation is performed by a series of voltage command iterations which progressively increase/decrease in amplitude at a constant rate determined by the computer. To assure that the computer does not exceed its real time throughput capacity, a restriction of 4 analog type command functions at a frequency of 20 cps has been imposed. Other functions requiring service by the uplink computer in real time includes:

a. Filing special S/C computer(s) error messages as provided by the downlink computer.
b. File all uplink commands.
c. Reading into high speed core the test checkout sequences or programs residing on mag tape.
d. Outputting on high speed printer a playback of filed S/C computer error messages.

SYSTEM ASSESSMENT

In our preliminary thinking of what happens on next generation S/C checkout, we began asking ourselves just what is our present capabilities. What limitations do we have in ACE and what areas should be worked on to make checkout more efficient and thorough. Three basic areas for assessment immediately come to mind which fairly well defines our areas of investigation or activity. These are:

a. Throughput capacity
b. Operational aspects
c. Hardware consideration or techniques

Increasing system throughput capacity is always a new design consideration, the ability to do more work faster and to provide more and better information. In the case of ACE, no longer has it become a desire. As new S/C come down the line there has been ever increasing requests for ACE to do more for the test people. It has now reached the point where ACE throughput capacity is a significant matter for consideration before approval of new requirements for implementation.

In order that we might be able to better evaluate ACE capability for both present requirements and assist in evaluating future systems, a search was made to find a suitable tool.

IBM's Simulation Program GPSS (General Purpose System Simulator) was recognized as the possible tool. Subsequent work has shown that indeed GPSS is capable of supplying us with a simulation tool that would give us answers on ACE and future systems. To date we have successfully simulated the downlink processing job which is best explained by use of Fig. 1 and Fig. 2.

Fig. 1 represents the entire Downlink Processing for 1 major cycle. The area between blocks 1 and 3 is the Interrupt Loop which is entered 50 times each second, with blocks 4 to 7 being the Executive Loop. A portion of the executive loop is accomplished once each prime frame until complete.

DOWNLINK TELEMETRY PROCESSOR

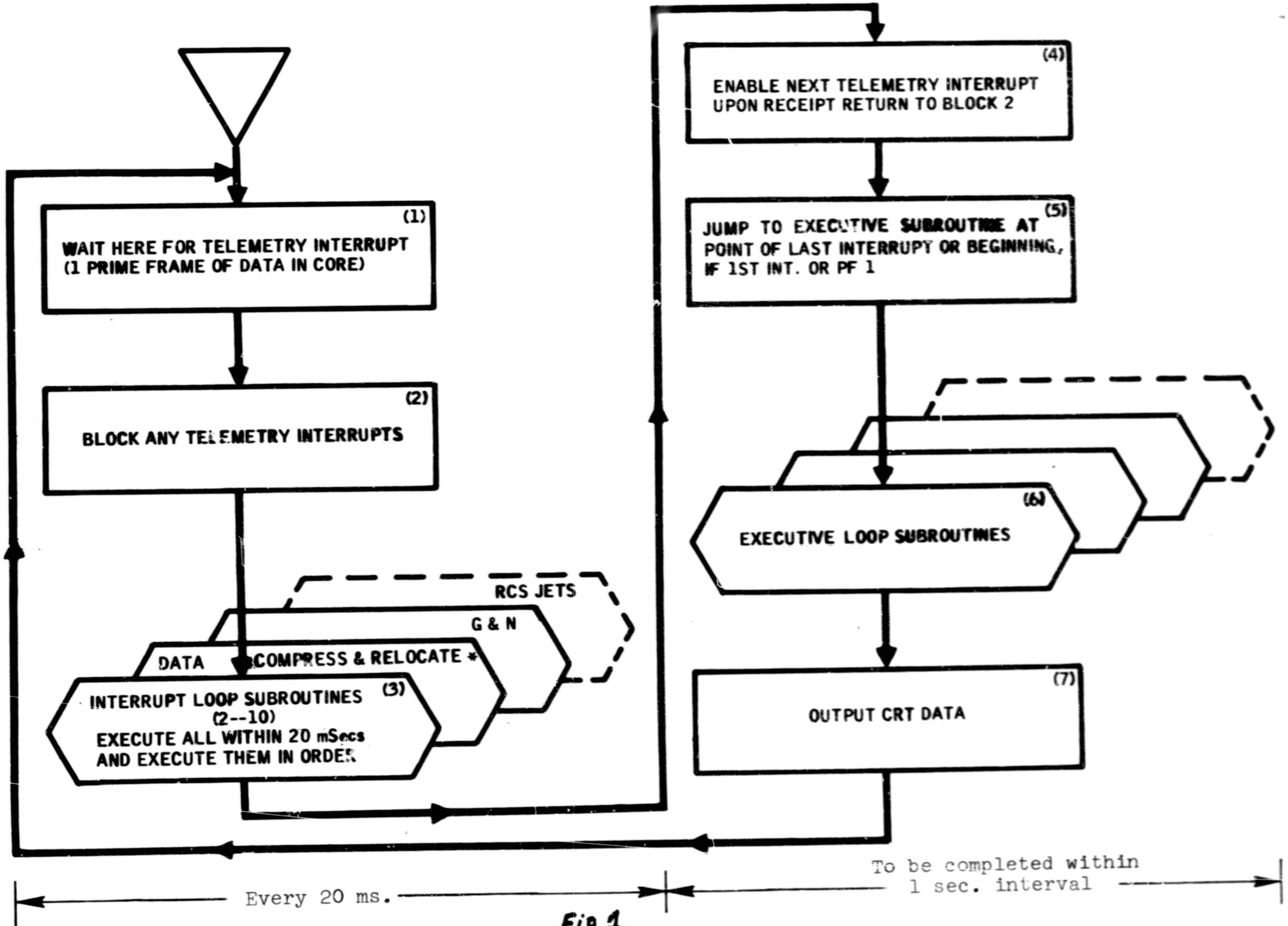


Fig.1

TIME CONSUMPTION OF THE DOWNLINK TELEMETRY PROCESSOR

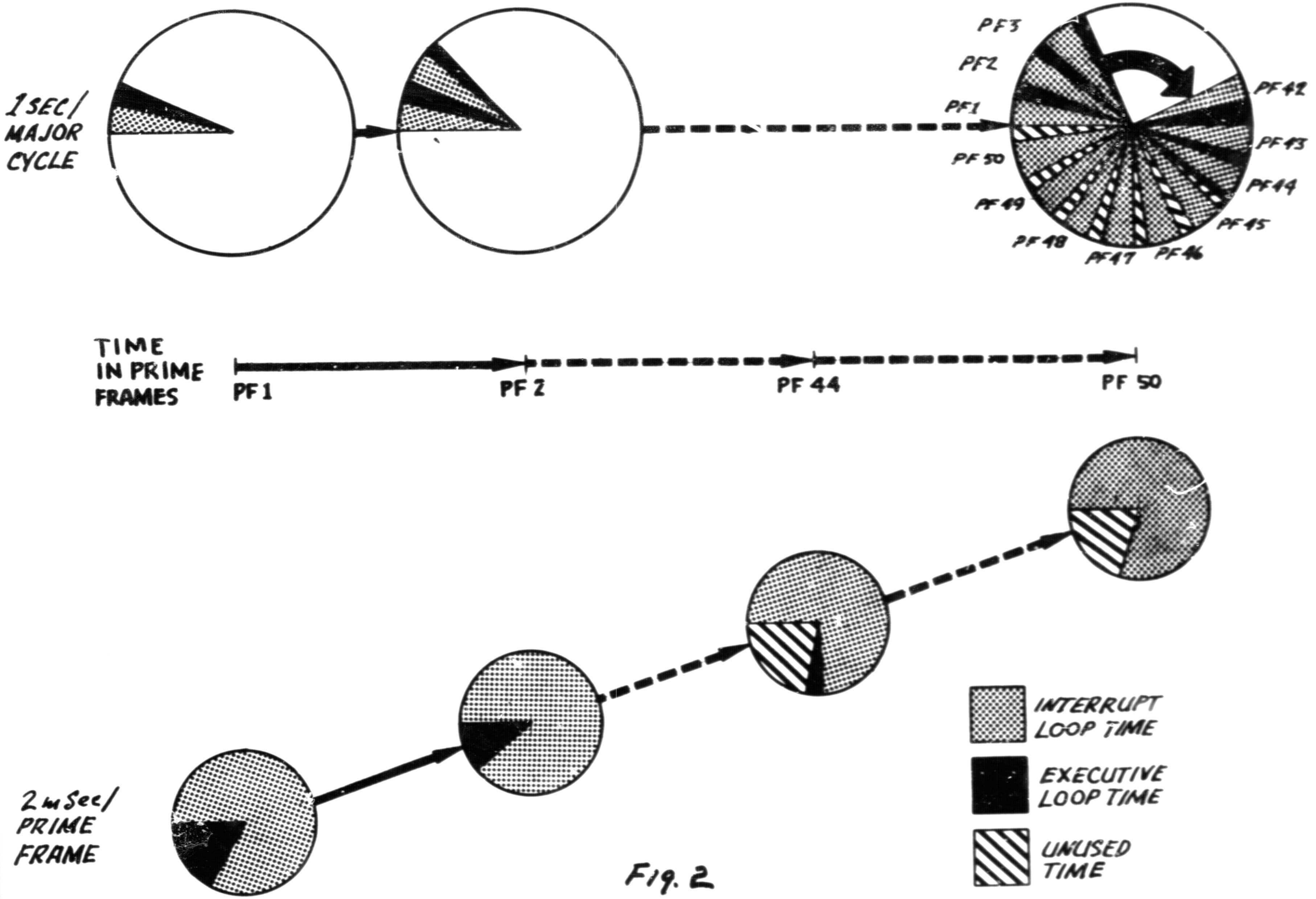


Fig. 2

Fig. 2 is a representation of how process time is consumed over the 50 Prime Frames of a major cycle. It shows the important requirement of maintaining program operation synchronous with telemetry data arrival.

Using the GPSS some of the major functions defined earlier have been analyzed with the findings presented below.

a. Data Compression and Relocation

$$F_{(x_i)} = 2.9 + A \cdot N_i + B \cdot M_i \quad \text{millisecs/P.F.}_i$$

where

A = .027

N_i = Number of Measurements Compressed/PF_i

B = .0054

M_i = Number of Measurements Relocated/PF_i

b. If M_i is equal to 50 then:

$$f(x_i) = 3.15 + A.N._i \quad \text{msecs}/PF_i$$

and for an N_i = 150

$$f(x_i) = 7.20 \text{ msec}/PF_i$$

The contribution for data Compression (AN) represents 56% of the total 7.20 msecs.

c. G & N Data Processing

$$f(y_i) = .9 + \sum_{t=1}^{m} T_s \quad \text{msecs}/PF_i$$

For $1 \leq t \leq m$ is normally 2, but may vary from 1 to 15. For each (t) there will be a difference (s).

where:

.9 is the time required for data identification and housekeeping.

T_s is the process time for a unique category (s):

T_s for s = 1 is .9 msecs for 15 Bit Scaling
= 2 is 1.2 msecs for 30 Bit Scaling
= 3 is .1 msecs for Event Display Conversion
= 4 is .25 msecs for Octal or Binary Conversion
= 5 is .25 msecs for Or'ing or And'ing two bits
= 6 is .0800 msecs for Data Filing

d. Executive Subroutine (s)

$$f\ (z_k) = N_k \cdot T_k + C_k$$

where k = Subroutine category
C_k = Constant usually zero
N_k = Number of Measurements in category (k)
T_k = Process time per Measurement in category (k)

T_k for k = 1 is .300 to .500 msecs. for conversions of raw data to engineering units. Add .050 msecs if calibration data is to be switched.

= 2 is .268 usecs. for Barometric Pressure Monitoring.

= 3 is .140 usecs. for conversion of Altitude Voltage to degrees.

= 4 is .130 msecs. for Time (CTE) conversion

= 5 is .890 or .222 msecs for S/S or 10 S/S Measurements respectively plus C_k = .090 msecs. for OR'ed Event conversion.

= 6 is .170 msecs. for Binary Display Conversion

= 7 is .033 msecs. plus C_k =.14 msecs for Analog rate of change detection.

= 8 is .300 msecs. for Inertial Measurement Unit (MU) angle conversion.

OPERATIONAL ASPECTS

Reviewing the system capabilities in terms of operational considerations, one must ask the questions what type of information must the C/O system supply to enable test personnel to make decisions on status of system under test; and how does one assure that everything - hardware and software - is ready for test and working properly. Information required includes:

a. System history - what tests have been performed previously and what was result of test.
b. On-line Quick Look retrieval - Display of previous test results and system trend.
c. Real Time Data to assure system functioning during test periods.
d. Status of test progression.

System history is provided by ACE-S/C via the digital compressed data tape, raw analog PCM recordings and strip chart recordings. This presently requires the support of a separate data processing facility to analyze mag tape recordings and present required output. On-line quick look retrieval during periods of testing is accomplished by ACE-S/C on a limited and controlled basis. Management of the operational testing activity must be very strict if playback is requested during real time testing to preclude the possibility of losing test data during this interval of time. Systems trends are not automatically processed by the ACE computer and operators have in the past been known to rely on manual log entries to keep status on system operation. Real time test data is now provided by ACE via the computer driven A/N CRT's. Twenty selectable pages of a fixed format (fixed for any specific test) is available to all system test personnel.

Test progression status in S/C checkout is strictly a manual function. The majority of sequencing from test to test is performed by verbal directions read from the OCP (Operational Checkout Procedures) by the test conductor. The verbal directions are then accomplished by the system test operators using the C-R-K START entry controls for ACE computer controlled functions. In the event a significant amount of automatic test sequencing is implemented, some form of progressive status display will be required. The ACE Software Program ADAP supplies this now to a limited degree.

Verification - One of the most significant problems faced by ACE-S/C to date has been that of systems (hardware and software) verification prior to start of test. Recognizing that improper hardware patching or incorrect computer coding can cause commands to be executed which could be catastrophic to S/C and personnel has caused much investigation by ACE system designers to prevent such a happening. Such concepts as using boiler plate S/C or house type S/C for dry runs have been investigated. Due to the fact that S/C are not a production type article and are continuously changing configuration, makes this approach not feasible. The concept now in practice by ACE is to perform a dry run of the test OCP using a simulated PCM input from magnetic tape. Through this technique, routing of data within the control room, through its patch boards, is verified as well as the CRT display format. Operation of the

C-R-K STARTS are executed which results in a command transmission which is then checked for proper address or routing of stimuli and the data transmitted. Since the present technique is very time consuming and requires considerable manpower, improved methods for hardware/software verification is of prime concern in any new system concept.

HARDWARE CONSIDERATIONS

Reliability - Although reliability of ACE-S/C hardware was a consideration in its initial design, only in the last year and a half has the importance of ground support equipment reliability become so recognized. Control of systems test from remote locations, coupled with the desire to provide more automatic control of testing, has pointed out the requirement for a continuous and absolutely reliable command link with the systems under test. In the case of such ground tests as engine firings or fuel cell control, the loss of ability to control becomes as big a problem as that of executing improper commands. The ability to automatically execute successive commands based upon system response imposes a significant reliability requirement on the response system and the communication link.

ACE-S/C hardware system design goals worked this reliability problem in several ways:

a. Switch capability to allow interchangeability of computer/control rooms.
b. Redundant Decoms
c. CRT Display backed up by decom driven events and analogs.
d. Ability to back up R-START entries with C-STARTS.
e. 100% redundant transmission of serial command data.
f. Redundant load and check modes of DTCS System.

ACE-S/C experience has shown that reliability of operation or backup consideration should be worked from a functional aspect rather than hardware backup. This is to say that providing redundant or parallel hardware in itself is not a sufficient consideration. System design must provide functional organization so that computers can be cross checking and assure each other's critical functions in the event one unit fails. Considering the remote control problem, new system design should provide the test article interface hardware with the necessary power and functional capability to fail safe or have adequate functional bypass. A point of interest is the ACE generation of periodic analog functions. Intermittent loss of data results in distorted wave shapes or erroneous signal levels.

Test Preparation and Verification - Routing of ACE controls and responses are controlled primarily by patch boards and junction boxes.

...rification of patching and routing is performed manually to ...monstrate that proper displays are driven and stimuli exists ...t the proper test points.

The ACE DTCS hardware provides logical checks up to the data ...gister. Feedback, or closed loop checks on data signal existence is not performed. Verification that the ACE-S/C DTMS is correctly ...ccessing and processing data is principally one of manual hard...are checks or testing. Although verification is accomplished, the time element becomes significant in this age where time is directly related to money. Repeatability or elimination of human errors is another goal to be achieved by automating verification through hardware design.

...OMPARISON WITH OTHER SYSTEMS

Since the implementation of the ACE-S/C System, several other C/O systems have been developed whose checkout role is similar to that of ACE-S/C. It is of some interest to correlate these systems' capabilities and philosophies against those of ACE. In the following material reference to the system will be made by its development period, i.e., mod 66 is system designed in 1966.

Number and Type of Computers

Mod 67 uses two Central Processing Unit (CPU) and associated peripheral devices as the Central Control Unit of the Data Processing Subsystem. Mod 66 uses one Central Processing Unit and ACE-S/C uses two (2) Control Data Corporation 160G computers as the central control units. Cycle times are as follows:

Mod 67 Memory Time = 850 Nano seconds
Mod 66 Memory Time = 1.50 Micro seconds
ACE CDC 160G = 1.35 Micro seconds

Mass Memory

Mod 67 uses two (2) Random Access Disc Memories, each with a capacity of two million characters. These Discs are used as part of both the on-line test equipment configuration and the off-line support system. Test sequences and randomly used test programs (Contingency and fault isolation routines) are stored on the disc for on-line use as well as historical data for trend computations and post-test processing. Mod 66 employs one Random Access Disc with a two million character capacity, and access time of 34 milliseconds (17 millisecond average). Usage is primarily on-line for test sequence storage, on-line computer operations and test data storage. ACE-S/C has no mass memory storage devices at this time.

Core Memory

Mod 67 uses shared memory banks for a total of 80K words of core memory. The two CPU's have access to all memory banks.

Mod 66 uses three memory banks one, 16K bank (CPU Basic Memory), and two 8K banks (One bank for PCM input and A/N Display, and one bank for command and discrete response data). Total core is 40K words.

ACE-S/C has a total core of 40K words * (8K in each CDC 1700G computer model with three 8K shared memory banks). Two external banks are assigned to PCM input, processing and A/N Display, and one external bank for command data storage and processing.

Program Memory Lockout

The Mod 66 System has Program Memory Lockcut which permits memory guards to be set up by the software. These guards can be assigned in blocks of 512 words and will prevent those areas from being written into, such as on an I/O failure, program error, peripheral device failure, etc. ACE-S/C and Mod 67 do not have this feature.

Power Fail Safe Feature

The Mod 66 System has Power Fail Safe features which causes the contents of programmable arithmetic registers to be saved (stored) if power fails. ACE-S/C and Mod 67 do not have this feature and as a result the programs must be recycled to a predetermined initialization point upon a return of power to the system.

PCM Data Recording

PCM data is recorded on analog tape in the Mod 66 (2 tape units) and ACE-S/C (3 tape units) systems. The Mod 67 System has one PCM analog recorder.

Independent Critical Function Monitor

The Mod 66 system contains provisions for monitoring up to 75 critical functions, as hardlined from the test area, at the operator control consoles. These functions are available to the

* Recently modified to 64K.

computer as inputs for status checking but the computer has no command interface with these hardlines. ACE-S/C and Mod 67 have no such "independent" monitor capability as a part of the ACE-S/C or Mod 67 checkout system. Both systems, however, have critical function monitor personnel stationed outside the control rooms with no interface, either active or passive, with the checkout system computers.

Independent Safing Controls

The Mod 66 system has provisions for twenty-four (24) hardline control functions available to the console operator. Data from these lines are available as inputs to the computer but no command interface is available. Mod 67 system design includes provisions for manually controlled switches on the Launch Control Console, hardlined to the discrete events rack to accomplish all required "safing" of the vehicle. This is designed as backup to the automatic safing capability of the software system. ACE-S/C has no independent hardline command lines for emergency safing control "as an integral part of" the ACE-S/C system. Such command lines are available but with no interface with the ACE-S/C computer system or ACE-S/C consoles.

Simulators for Closed Loop Verification & Fault Isolation

Both Mod 67 and Mod 66 design description indicate that hardware simulators will be available to "close the loop" between the command transmission system and the Data Monitoring System. At this time ACE-S/C has no such hardware simulators for closed loop program verification and/or fault isolation.

Internal Computer Clocks

Mod 67 and ACE-S/C each have countdown and real time available as inputs from external equipments. In addition, the Mod 67 system includes two "Delta timer" units (one for each CPU), each of which allows the software to request up to eight (8) interrupts when the pre-set delta times expire. ACE-S/C has the capability of requesting an interrupt upon expiration of a delta time interval, but only one at a time.

CPU Fault Timers

The Mod 67 system console I/O units contain two "watchdog" timer units (one for each CPU). During normal operation the CPU's periodically, via direct I/O pulsed outputs, provide a reset command to these timers. If one of the timers "times out" (i.e., if the CPU does not reset it) the timer locks-up, lights a light on the console,

and provides an interrupt to the other CPU. Once this occurs, the CPU can only be reset through a CPU restart procedure which includes a CPU Self Test.

Console/Command Inhibit Feature

The Mod 67 system has the ability, either through console operator input or pre-programmed procedures, to "danger tag" any command to inhibit transmission. The Mod 66 system has console lockout features which require that the test conductor "unlock" any operator console before any active command can be initiated from that console. Otherwise, the console is in a passive/monitor mode. ACE-S/C has neither of these capabilities.

Command Transmission

In the case of both Mod 67 and Mod 66, great emphasis is placed upon decreasing the probability of transmitting an erroneous command as a result of a hardware failure in the uplink system. Data presented on at the Mod 66 System indicated that the probability of transmitting an erroneous command due to hardware failure is 5.15 x 10^{-11} or one command in 1.94 x 10^{10} commands. The Mod 67 System presents no statistical breakdown of failure mode effects but the design criteria that "no single failure shall cause a hazardous condition for the vehicle or personnel" results in the inclusion of the "majority voted stimuli" system, and in the proposed redundant operation and configuration of the computer system. It should be noted that this redundancy along with the various features, such as the CPU Watchdog Timers, and redundant Delta Timer Units, also provides Mod 67 with a negligible probability that a command will NOT be transmitted when it should be (such as the reset command for a momentary relay closure, etc.). That is, this redundancy precludes the possibility that a computer halt or malfunction will result in NOT transmitting a command that should be transmitted. The Mod 66 and ACE-S/C Systems have no such protection. In this case what is required is to provide rapid alarms that a failure has occurred, and manual backup capability for safing the test article. The operation and procedure for such actions in this circumstance are not available from the mod documents.

Data Display

The Mod 67 design description, since it contains descriptions of the software and general test philosophy, indicates how the operator consoles will be used. The Mod 67 System is a "Management by Exception" system wherein only those data which have changed or are specifically requested are routed to the displays. The CRT's

e to be used for both data and comments (roughly one half page r each). The comments originate from the test sequence itself r from operator keyboard input. The operator has a "selective RT erase and save" option, as well as the capability of requesting rend calculations and plots (i.e., get present values of measure- nt XX and plot it, indicating when it will go out of limits). E-S/C CRT page are pre-specified by the software without selective ata requests available to the operator other than page changing.

E II

Concepts - Introduction

Design and development of a new generation checkout system t not reflect only an attempt to improve hardware functions or resolution of present day system limitations. After working h the present Apollo Program and Manned Spacecraft checkout, appears to us that a significant change in operations concept applicable. Experience to date indicates that checkout is really o basic jobs which must be accomplished by one total system which tightly integrated together. One job is that of real time pro- sing which is recognized as being stimulus generation, response valuation and automatic progression of testing based on Go/No Go ystem outputs. The term automatic checkout is probably most pplicable here. Any other concept of automated checkout is almost mpossible to define. Hardware design to permit this automatic tion is well understood and requires only the proper management irection at time of original system design. It is felt, also, that this type of automatic concept is incorporated, it is best to ocate the necessary hardware power as close to the test article possible. This accomplishes three objectives:

a. Minimizes personnel operating or interference with the automatic checkout operations.
b. Allows for more reliable system operation since hardware linkage errors due to distance and transmission mediums are reduced.
c. Permits individual system testing with a minimal equipment complex.

he second job that a checkout system must accomplish is that of ata management and a man/system interface. The task of data manage- ent is a near-real time world which should become a data by exception unction. Test status information, post test and quick look analysis, ontrol over the overall test progression, availability of detailed ystems response data, and capability to override or provide backup o the automatic portion of the system.

DESIGN - GENERAL

General purpose digital computers will be used with a multiple, non-dedicated central processor configuration being employed. This approach provides several modes of operation which are acceptable despite failure of a major component, such as a memory bank or a processor. Capacity and computational power are greatly increased to provide additional on-line processing. Storage of historical data for real-time or near real-time retrieval will be possible with the inclusion of mass storage devices (drum/disk).

The system employs command storage, data processing and data compression within the immediate vicinity of the spacecraft, thereby eliminating total and constant dependence on the transmission link between the data processing and control area and the test vehicle. The remote portion of the system will utilize a small processor for initiating programmed sequences of stimuli commands. The processor will ascertain that the resulting measurements and prerequisite conditions are satisfactory for continued test operation.

The control and display consoles are reduced in quantitative display provision. A dual CRT system provides simultaneous real time data display in any desired format and selectable historical data for reference to system parameters. The computational power will provide for routine correlation of events and evaluation of analog data with the results presented on summary displays and alphanumeric CRT's.

Control of spacecraft testing is provided by alphanumeric keyboard and "fixed function" command entry panels. Some hard-wired functions are incorporated for emergency control.

Data Recording and Analysis will be provided by analog magnetic tape recorders, high speed printers, CRT hard copy devices, and strip chart recorders. A log typer will provide computer entry from the recording and analysis area. The principal function of this sub-system to provide, in a variety of formats, a record of information which may be reviewed or analyzed in relation to time and other functions.

Spacecraft Vicinity Equipment Description

The Spacecraft vicinity equipment provides the following functions:

a. Command reception and reformatting from the central computer area. The 24-bit command messages include both specific stimuli generation words and instructions for the sequence

and relationship of the commands given and response received.

b. Storage and execution under self control of these command sequences. This is accomplished with an airborne type general purpose digital computer.

c. Stimuli function generation. These stimuli may be sine waves, contact closures, DC levels, square waves, triangular waves, complex waveforms and digital words.

d. Measurement collection and conditioning. Data will be gathered from addressable sensor channels. This design provides reduced data transfer and complete flexibility of sample rates. The sample sequence and frequency will be determined from a stored memory control unit which is loaded via the remote computer. Signal conditioning is provided to bring the GSE and Spacecraft testpoint voltages to the programmer working levels.

e. Measurement checks - The programmer will perform a fixed and floating limit check on the analog data and store the data in its memory for access by the computer. The airborne telemetry will also be routed through the remote computer interface circuitry for access.

The stimuli generation and measurement collection equipment will be modular and the power and word structure will be sufficient for expansion to handle future application.

The external interfaces of the remote system are 1) computer-to-computer 24-bit digital command and program loading link. This transfer is approximately 1 million bits per second, when active. 2) Serial checkout data - 24-bit GSE and S/C data plus address. This transfer is at a rate of one million bits per second. 3) Airborne PCM measurement data at 51.2 KC with 8-bit words. 4) Bypass command link - This is a 24-bit serial line to provide backup command capability in the event of remote computer failure.

Central Computer Complex Description

The Computer Complex System performs the functions of test control, data processing, command/response relationship evaluation, command recording, and measurement data formatting for display and recording.

The computing system consists of 3 (number dependent on processor power) central processor units, approximately 125 thousand 32-bit words of core memory, and 3 Input/Output processors which effect data transfer between memory and peripheral devices. The peripherals include the following: (quantities are approximate) two mass storage devices such as disks and/or drums, six tape transports, a card

reader, a card punch, two high-speed printers, telemetry processors and a computer data translator.

The CPU's and the Input/Output processors are interconnected in such a manner as to allow control and access to each other's assigned memory and devices. This, along with proper software control allows the failure of one of these devices and the assumption of its assigned duties by another of the identical hardware units. The prerequisite condition for this "failure absorption mode" is partial loading or the relegation upon failure, of some nonessential real time activity, such as data stripping, to a post test job. The hardware and software will employ failure sensing to effect the job transfers, i.e., parity error checking, power sensing, timers to prevent program hang up, etc.

One of the more significant data processing jobs of the computer complex is the compression and storage of measurement values within closely specified tolerances for real time retrieval and display to provide historical and trend predictions for the test engineer.

Control and Display Subsystem Description

The Control and Display Subsystem will contain human factored consoles with alphanumeric and fixed function keyboard entry controls and alphanumeric and graph plotting CRT displays. Among the fixed function keys will be hardwired critical or emergency controls. Event indications will also be provided as outputs from the Input/ Output processor; these events will be summary or computed type events as well as raw S/C and GSE events which are significant enough within themselves to warrant constant test engineer surveillance. The CRT System will be capable of CCTV presentation, with camera select control.

Other pushbutton or thumbwheel type controls will provide the selection of test modes such as single step or automatic and direct program control such as Hold, Master Clear, Keyboard Execute, Update Hold, etc.

Special control and monitor devices will be required on the Test Conductor and Bio-Med Consoles to accomplish their unique functions. Also, a facility monitor console will be custom-designed for the unique nature of facilities such as test chambers at MSC.

Generally speaking, the other consoles will be identical, with the basic design being based on the quantity of control and display required by the largest flight article subsystem. The consoles will receive and generate serial data in their interface with the Input/ Output processor. This approach provides simpler, more reliable

interconnect cabling, thereby allowing the introduction of data distribution check circuitry to verify the fidelity of the console data bus.

Data Recording and Analysis Subsystem Description

The recording and analysis equipment will provide recorded raw data, processed data and derived data for analysis by the test engineers and analysts. This capability allows a determination within minutes or hours after the actual test operation, whether or not the vehicle and/or facility operated satisfactorily.

Digital magnetic tape recorders will be utilized to record the raw data from the remote area for possible future use. The data, of course, will have been remotely compressed to eliminate unnecessary tape usage.

Strip charts will be used to trace analog data for time and inter-measurement correlation. A logging printer will be used for event recording against time. The channels assignments may be changed during the course of the test to achieve maximum data relativity and provide efficient recorder usage since the data is input from the computing subsystem.

The CRT Photo Recorder will capture for post test analysis and reference, those conditions which are significant to the test engineers course of action and which precipitate a test decision.

This subsystem provides a very significant capability in conjunction with the increased computational capability of the system. The tempo of spacecraft checkout does not permit any residual review or qualitative (how good or how bad) analysis in real time. However, efficient and successful test operations consistently require a qualitative judgment based on very recent or just completed completed test data.

Time code generation, real and countdown, will be provided by this subsystem for recording and distribution to the computing and control and display subsystems.

Automated Facility Interface

Control and monitoring of facilities such as the chambers at MSC will be treated in a manner similar to the S/C system. A S/C vicinity type system will control and monitor the facility, under the Central Ground Station Control, in the same manner as the S/C systems are managed.

The Computer Complex, Control and Display and Data Recording and Analysis are compatible with the monitor and integration of the facility data. This integration becomes very desirable, if not mandatory, during spacecraft checkout to relate the performance of each to the other.

The capability for control of the facility from the Facility Consoles within the control room will exist with the development of sufficient computer software to perform the large number of individual functions.

S/C INTERFACE EQUIPMENT DEVELOPMENT

General

It is possible to design the most sophisticated, automated checkout system available and yet not be able to efficiently checkout the spacecraft. A link or interface must exist between the checkout station and the system under test. This Interface Equipment must be such that it augments total system capability, rather than becoming the proverbial weak link. It should be designed such that certain mundane but necessary tasks are performed independently, thereby freeing the Control Stations for more efficient operation. The hardware should be designed with software in mind, and trade-offs performed. It then becomes possible to define complete tests that are better performed at the S/C by the Interface Equipment. The next logical step is to give the Interface Equipment a decision-making capability, thereby providing more flexibility. Once this is done, closed loop testing, i.e., command/response verification, becomes possible and the Central C/O Station is free to do its data processing, reduction, display, etc., more efficiently. After this type of analysis is made, it becomes readily apparent that this area is one whereby many improvements can be made, at a relatively low cost, to the present ACE System. To this end, inhouse work has been going on at MSC utilizing NASA/Contractor personnel to develop a prototype system to replace the present S/C interface equipment (DTCS/DTMS). The remainder of this paper is concerned with delineating the progress that has been achieved, and the approach taken.

System Design Philosophy

The primary purpose of the ACE II Remote System, as explained above, is to provide a flexible spacecraft interface for the ACE Ground Station for future as well as present S/C checkout. While future requirements are not clearly defined at this time, current requirements serve as guidelines. In addition, current problems are also well-known (unfortunately) and could be analyzed. However, the

ADVANCED SYSTEM REQUIREMENTS

1. PROVIDE THE CAPABILITY FOR INDEPENDANT OPERATION TO FACILITATE CLOSED LOOP TESTING AND FAULT ISOLATION.

2. INCLUDE THE MEASUREMENT & STIMULI REQUIREMENTS OF THE PRESENT CARRY ON SYSTEM WITH EXPANSION CAPABILITY.

3. PROVIDE CONTINUOUS SAMPLING OF MEASUREMENTS AT 5 TIMES THE RATE OF PRESENT DTMS.

4. IMPROVE THE STIMULI CAPABILITY BY PROVIDING SOLID STATE SWITCHES, PROGRAMMABLE FUNCTION GENERATOR AND PROGRAMMABLE LENGTH DIGITAL WORD GENERATOR.

5. INCLUDE PROVISIONS FOR MONITORING FLIGHT PCM.

6. PROVIDE A MEANS OF SOFT WARE VERIFICATION.

SYSTEM FEATURES & CAPABILITIES

1. BACK UP MODE OF OPERATION IN CASE OF COMPUTER FAILURE
2. REMOTE MEASUREMENT & STIMULI CAPABILITY
3. BUILDING BLOCK TECHNIQUES UTILIZED IN PACKAGING TO PROVIDE FLEXIBILITY & EXPANSION CAPABILITY
4. CONTINUOUS MONITORING OF EMERGENCY TYPE INPUTS
5. HIGH SPEED MEASUREMENT - APPROXIMATELY 30 μS PER CHANNEL
6. FLEXIBLE MEASUREMENT SAMPLING RATES & PCM FORMAT - DETERMINED BY PROGRAMMABLE SEQUENCER
7. CAPABILITY TO INTERROGATE & DISPLAY CURRENT STIMULI OUTPUT STATUS
8. CAPABILITY PROVIDED FOR THE COMPUTER TO ACCESS ANY FLIGHT PCM PRIME FRAME
9. BUILT IN MODULE CHECKOUT CAPABILITY
10. FLEXIBLE DISPLAY & CONTROL - DETERMINED BY SOFTWARE

remote system design was not based on solving these problems alone, but an effort was made to determine the most flexible, efficient spacecraft interface for ACE. It follows that the basic design of any future ACE II Ground Station will be somewhat influenced by the Remote System Design. This appears desirable since a fully integrated spacecraft checkout system, from the ground station to the spacecraft will then exist, thereby providing for complete automatic closed loop checkout or any degree thereof. A basic block diagram of the development system is shown in Figure 1.

There are four modes of operation available to the Remote System. These are a) completely automatic, b) ACE Ground Station Mode, c) monitor mode, and d) fault isolation mode.

Automatic Mode

In the Automatic Mode test sequences are loaded into the Remote Computer Memory from the ACE Ground Station CPU. The Remote Compute then loads the proper PCM format into the sequencer memory. At this point, monitoring sequences would begin. The Data Acquisition System has a basic capability of 32,000 words per second. There is no longer a continuous PCM stream sent to the Decom. Instead, the Data Acquisition System functions as follows:

A word is first read from the sequencer memory. This word contains the address of a data point in the Remote Measurement Unit. This address is transmitted serially at 5 mc to the proper RMU and is decoded to enable one data point. Certain error checks are made to insure the proper data point response. The RMU then sends a 23-bit word back to the Sequencer and Control Unit. More error detection checks are made, along with both a fixed limit check and floating limit check. Then, at the proper time, the data, including the address and results of the limit check are gated to the Ground Station at 1 MB. A buffer interface unit at the ACE Station then provides for direct memory access to the computer, or can provide a direct driven display capability. The data is also available to the Remote Computer, along with coded interrupts, if any of the error or limit checks fail. This process is repeated every 31.2 μseconds. In addition, every 640th word contains a prime frame count from 1 to 50.

This approach has the advantage of providing a dynamic data acquisition system to replace the static DTMS. Some of the major differences are:

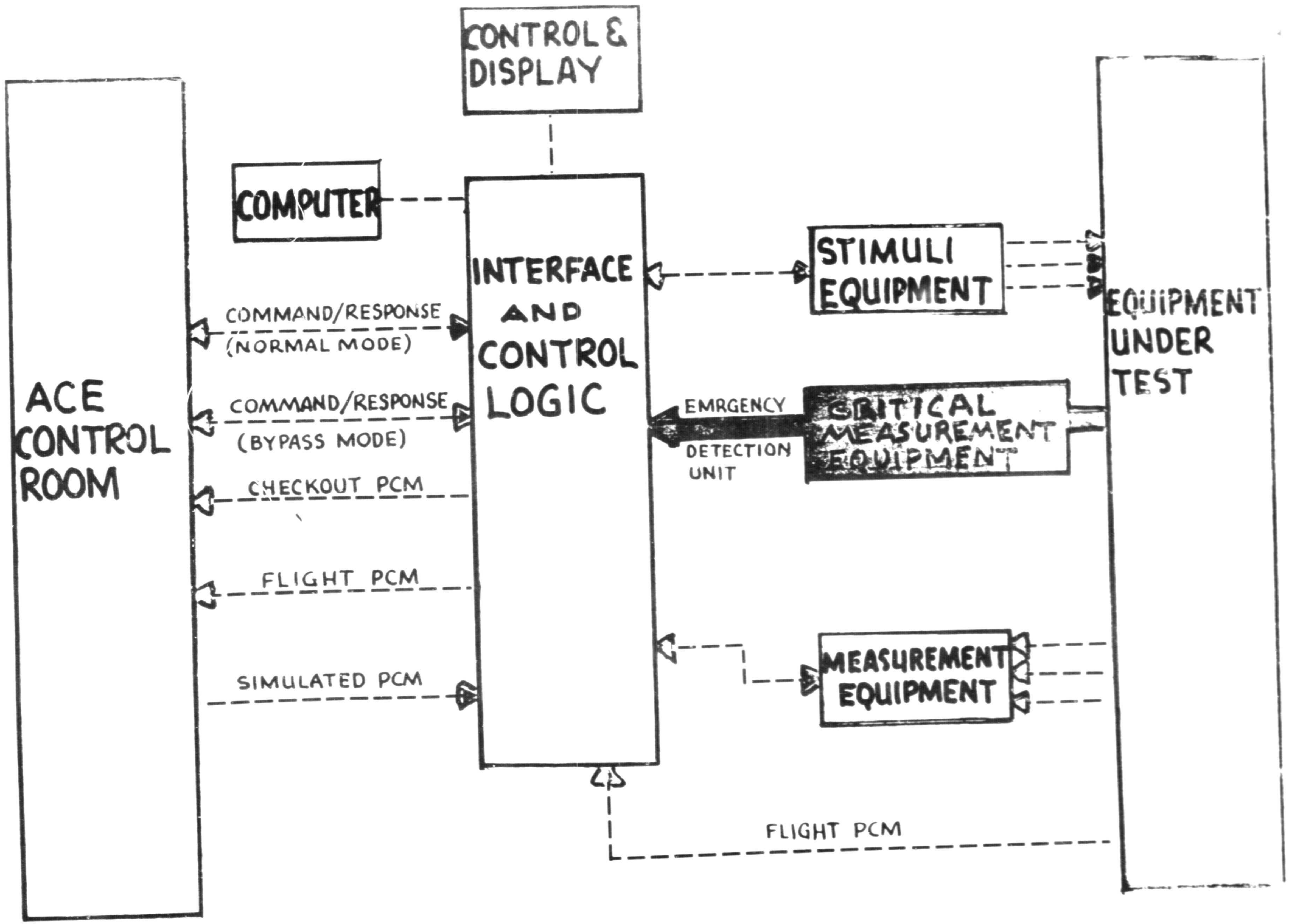

CONTROL & DISPLAY
COMPUTER
ACE CONTROL ROOM
COMMAND/RESPONSE (NORMAL MODE)
COMMAND/RESPONSE (BYPASS MODE)
CHECKOUT PCM
FLIGHT PCM
SIMULATED PCM
INTERFACE AND CONTROL LOGIC
EMRGENCY DETECTION UNIT
STIMULI EQUIPMENT
CRITICAL MEASUREMENT EQUIPMENT
MEASUREMENT EQUIPMENT
FLIGHT PCM
EQUIPMENT UNDER TEST

Fig. 1

a. A flexible data point address selection that makes available any sample rate up to 32K/sec., and is changeable by software.
b. Error detection that certifies the data is actually data from the data point addressed.
c. Fixed limit checks at the S/C vicinity for prompt corrective action if necessary.
d. Interrupt capability to allow the remote computer a flexible interface.
e. All data is available to the Remote Computer when desired with no sync or look-up tables required.
f. Floating limit checks are performed by a combination of hardware/software in the vicinity of the S/C and made available to the Ground Computer.
g. Sync problems are eliminated since there now exists word sync in the form of an address, and prime frame count.
h. Direct memory access to the ACE Computer is provided.
i. Direct driven display and/or recording capability is provided.
j. A 1 MB transmission rate makes available the necessary time for a parity error encoding check to insure against transmission errors.
k. An interface is provided for the Remote Computer to generate data point addresses for fault isolation, and to reduce the danger of single point failures.
l. Cabling reduced to one cable per RMU.

The Critical Monitoring Unit, an independent portion of the Data Acquisition System will provide 2 functions. The first function is constant monitoring of up to 16 selected critical functions. These will primarily be threshold detection type functions that will interrupt the Remote Computer when a critical limit is exceeded. This approach deletes the necessity of having to provide extremely high sampling rates in order to detect a failure, thereby relieving the RMU to do its job more efficiently. A second function of the RMU is to provide real time waveform analysis of gliches on 6 power busses. The lack of this capability is a current problem and would definitely be a future one. When a glitch occurs on any one of the six busses, the data would be digitized and sent to the ACE Central Computer over the uplink communication lines. There the glich could be reconstructed. Again, this eliminates the necessity of a high sampling rate in the normal PCM data.

In summary, the RMU provides the following functions, none of which are being presently performed:

a. Independent, constant critical monitoring of up to 16 measurements with interrupt capability to the Remote Computer for prompt analysis/corrections.
b. Constant monitoring of S/C power busses and real time reconstruction/analysis of power glitches to allow accurate S/C system troubleshooting.
c. Both functions performed independent of the RMU and do not fill up the PCM format.

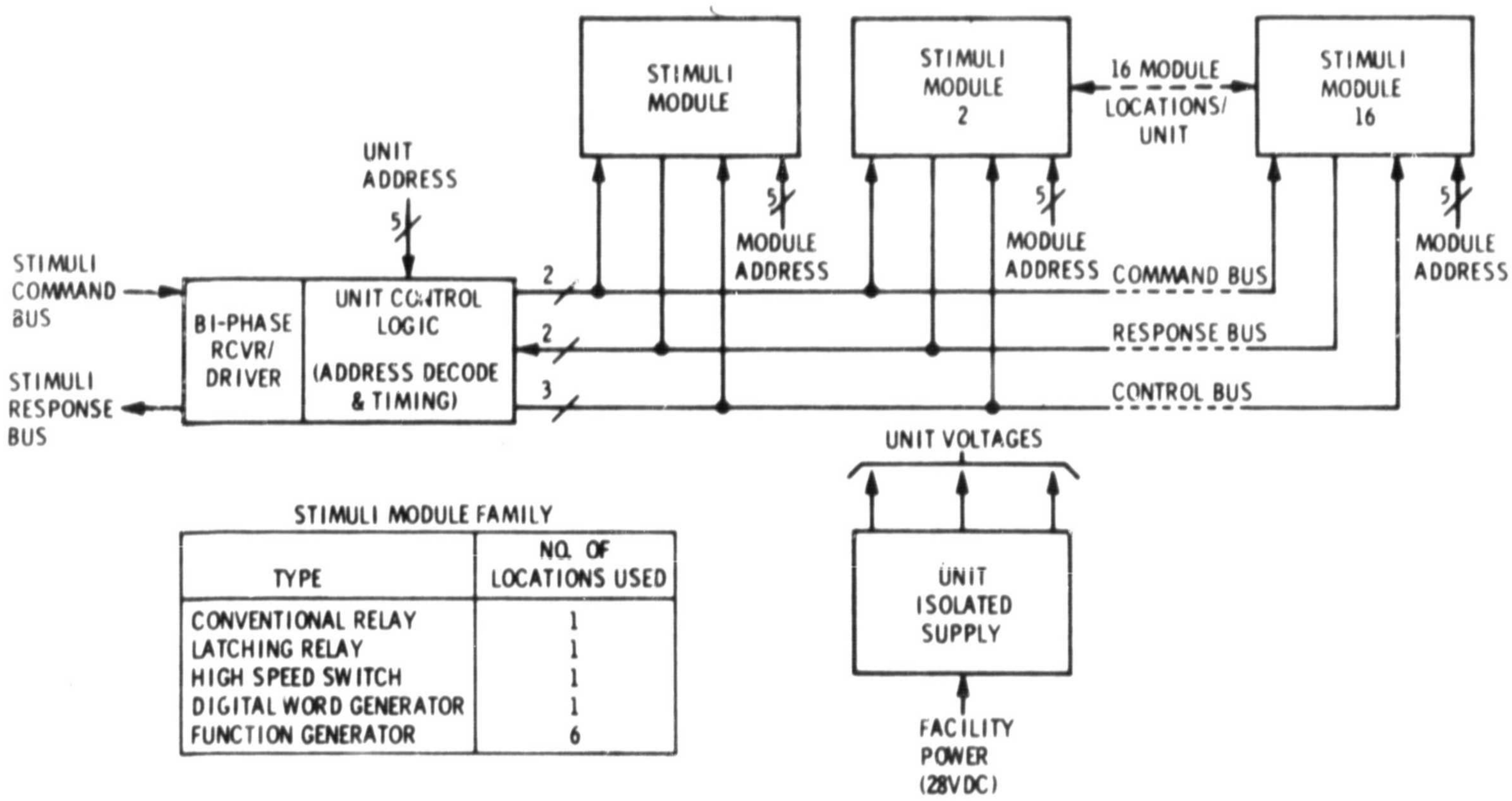
The Stimuli Equipment is under direct control of the Remote Computer in the Automatic Mode, with ACE retaining an override capability on the Bypass Link as well as the computer-to-computer link. A RSU has three types of commands issued to it. These are load, execute and interrogate. Upon receipt of a load command, certain conditions are set up to prepare for the execute command. The execute command then applies the stimuli to the S/C system under test. The interrogate command does not apply or change any stimuli but allows a means of determining the state of the stimuli modules if desired. There are four basic types of stimuli modules. These are Relay, High Current Solid State Switch, Programmable Digital Word Generator and Function Generator Modules. The output of any of these modules can be monitored by having the computer access the sequencer memory of the Data Acquisition System at any time. In addition, the Function Generator may be set up, verified on the D/L and then switched to the S/C by the Remote Computer. A provision is also available for sampling the output after applying it to the S/C through the RMU A/D convertor.

The basic advantages of the RSU approach are:

a. Single cable for each RSU utilized.
b. Internal switching available thereby eliminating problems associated with using C14-202.
c. Function Generators relieve computer load.
d. Solid State Switches provide faster, reliable operation.
e. Programmable digital word generator fulfills present requirements of both the G & N Buffer and the 410-31110 AEA Buffer, as well as being flexible for any future Digital Word Requirements.
f. The system operating speed increased by a factor of 20 or greater.
g. System is inherently designed to function with the RMU/Remote Computer for a closed loop testing.
h. Interrogate mode available to determine state of the RSU at any time.
i. All Function Generators may be verified before applying to the S/C and at any time desired thereafter.

The RSU is not presently being developed, due to manpower shortage.

BLOCK DIAGRAM REMOTE STIMULI UNIT



STIMULI MODULE FAMILY

TYPE	NO. OF LOCATIONS USED
CONVENTIONAL RELAY	1
LATCHING RELAY	1
HIGH SPEED SWITCH	1
DIGITAL WORD GENERATOR	1
FUNCTION GENERATOR	6

However, a substantial portion of the design is complete and development will begin as soon as possible.

ACE Ground Station Mode

Two uplink lines provide communications between the Remote System and ACE Stations. The normal test loop is a computer-to-computer link as described in Paragraph A (automatic mode). However, a bypass link is provided whereby the ACE CPU can lock out the Remote Computer and take over stimuli generation. Complete sequences such as ADAP could be run, or manual entry of commands from R-STARTS, etc. could be exercised. The downlink data would be unaffected by this action and would continue to be processed in the normal manner. However, the primary function of this link is to eliminate a remote computer failure from halting testing, with the S/C in an unsafe condition. Since the Remote Computer keeps the ACE CPU updated as to the point in test, and since an interrogation mode is available in the RSU, the change-over from Remote Computer Control to ACE CPU control should be affected with a minimum of hold time.

Monitor Mode

In the Monitor Mode no stimuli commands are being generated by the Remote Computer. The D/L functions as in automatic mod with all limit checks being performed and the data being processed as usual. During this mode of operation the data point addresses may be generated by the sequencer and control memory or by the remote computer. This approach has the advantage of making available a redundant path for providing these addresses.

Fault Isolation Modes

The Remote System has an inherent design capability which facilitates fault isolation. Both the RMU and RSU are dynamic subsystems and respond upon receipt of commands. Address capability is included down to a replaceable module, with the computer having the ability to determine the faulty module by analyzing the response. The address of the faulty module can be displayed and the module quickly replaced. The fault isolation subroutine may be run automatically by the Remote Computer, or manually from the display subsystem. It follows that a hold in testing must accompany this mode, but the design of the RSU and RMU are such that the down time will be minimal. In addition, the RMU may still function in the monitor mode only if the problem resides in the RSU.

SYSTEM DESIGN DESCRIPTION (GENERAL)

The basic system design is shown in Figure 1. Everything except the Remote Stimuli Unit and its interface is currently being developed. The logic family selected for use was the Honeywell 3C micro-pak 5 megacycle line. This logic was selected for several reasons. First, it provides a quick efficient means of breadboarding up circuits since the integrated circuits are already mounted on plug-in cards. Racks are available with both taper pin or wire-wrap connections for ease of subsystem assembly. Second, the logic family itself is quite complete leaving only special purpose parts to be purchased from other vendors. Examples of this are the General Instruments analog switches, which can be mounted on blank 3C paks for ease of assembly, and the Analog to Digital Converter by Bunker-Ramo. The A/D selected for evaluation uses a cyclic, continuous tracking conversion technique. With this approach a 1 mega-word/second rate is available. This speed, in conjunction with 5 MC intersystem signal transmission, makes available the 32K/sec. PCM word rate.

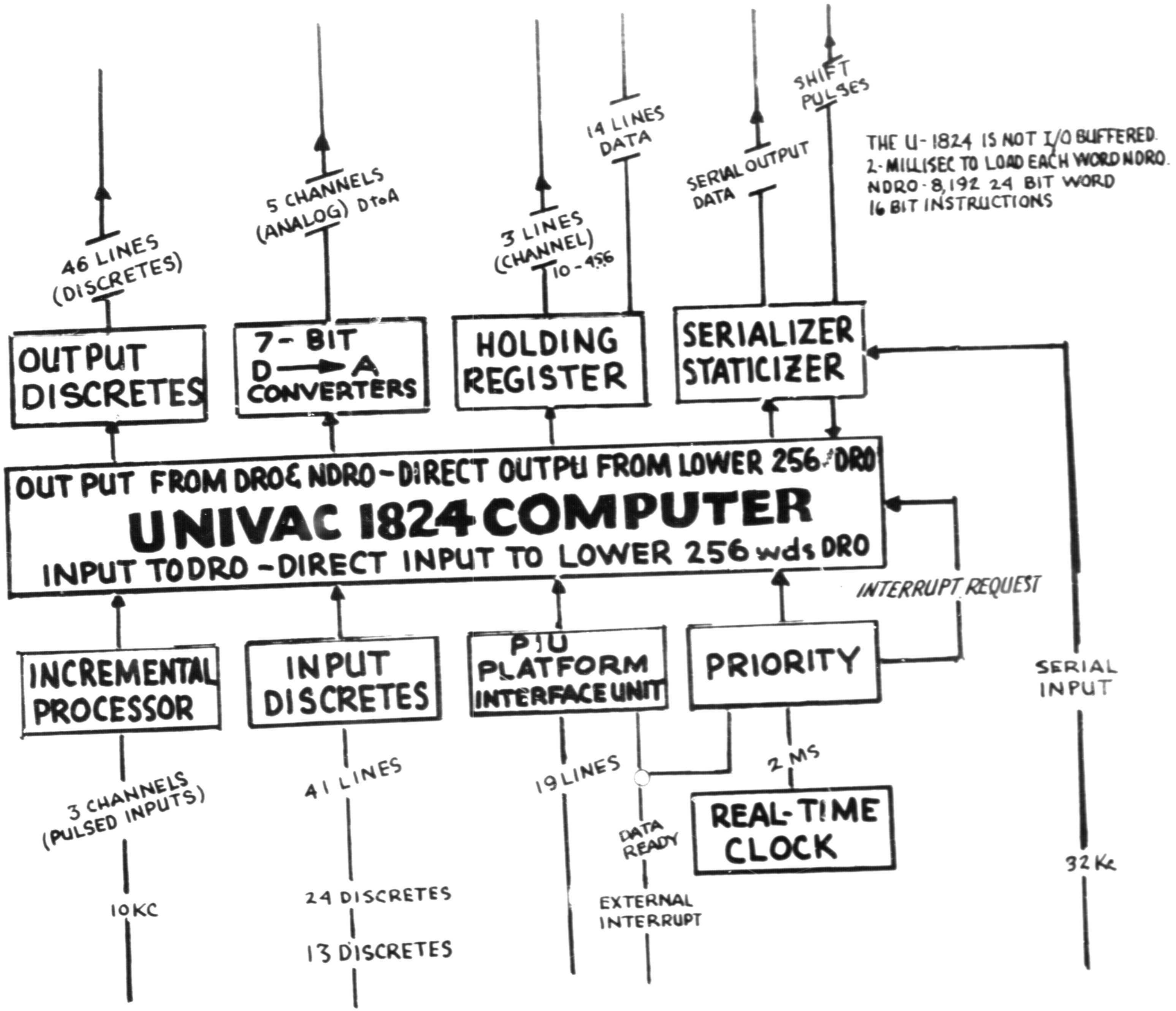
The logic to be used in the Remote Stimuli Unit is available as surplus from cancelled programs. These are the 1 mc potted modules currently in storage in the CSB development lab. As manpower becomes available, design of the RSU will begin.

Computer

At present, the Univac 1824 Computer, on loan from the AF, will be utilized. This is a special purpose computer with very limited capability and is being used only to demonstrate system concepts. One ground rule being emphasized is that the Remote System Design will not be influenced by the use of this computer. Any special interface equipment required will be external to the Remote System. As the design proceeds, specifications will be written, based on the design, for an ultimate computer. Where certain functions can be performed by software or by hardware, trade-offs will be determined and the approach deemed most feasible taken, based on the results of these trade-offs. A block diagram of the 1824 is shown in Figure 2.

Display Subsystem (General)

A limited display capability will exist in the Remote System. The status of the 16 critical measurements will be continuously displayed. In addition, the operating mode will be displayed. Under computer control, any "out of tolerance" measurement points may be displayed. In the fault isolation mode only, command may be generated to either the RSU or RMU and the results displayed.



46 LINES (DISCRETES)
5 CHANNELS (ANALOG) DtoA
3 LINES (CHANNEL) 10 - 456
14 LINES DATA
SERIAL OUTPUT DATA
SHIFT PULSES
THE U-1824 IS NOT I/O BUFFERED.
2-MILLISEC TO LOAD EACH WORD NDRO.
NDRO-8,192 24 BIT WORD
16 BIT INSTRUCTIONS
OUTPUT DISCRETES
7-BIT D → A CONVERTERS
HOLDING REGISTER
SERIALIZER STATICIZER
OUT PUT FROM DRO & NDRO - DIRECT OUTPU FROM LOWER 256 # DRO
UNIVAC 1824 COMPUTER
INPUT TO DRO - DIRECT INPUT TO LOWER 256 wds DRO
INTERRUPT REQUEST
INCREMENTAL PROCESSOR
INPUT DISCRETES
PIU PLATFORM INTERFACE UNIT
PRIORITY
SERIAL INPUT
3 CHANNELS (PULSED INPUTS)
41 LINES
19 LINES
2 MS
REAL-TIME CLOCK
DATA READY
10KC
24 DISCRETES
13 DISCRETES
EXTERNAL INTERRUPT
32 Kc

Fig. 2

CONTROL & DISPLAY CAPABILITIES

CONTROL

1. SELECT & EXECUTE A PRE-STORED TEST OR SEQUENCE OF TESTS.
2. COMPOSE & STORE A NEW TEST OR SEQUENCE OF TESTS.
3. CHANGE OR DELETE PRE-STORED TESTS.
4. INITIATE FAULT ISOLATION AND VERIFICATION ROUTINES.
5. INITIATE SAFING ROUTINES.
6. HALT A TEST IN PROGRESS.

DISPLAY

1. ANY MEASURED PARAMETER.
2. PRE-STORED TESTS.
3. PRESENT STATUS OF STIMULI.
4. STORED LIMITS OR CONSTANTS.
5. ANY STORED DATA.
6. TEST RESULTS.
7. STATUS OF EMERGENCY INPUTS.

CONTROL & DISPLAY CAPABILITIES

CONTROL

1. SELECT & EXECUTE A PRE-STORED TEST OR SEQUENCE OF TESTS.
2. COMPOSE & STORE A NEW TEST OR SEQUENCE OF TESTS.
3. CHANGE OR DELETE PRE-STORED TESTS.
4. INITIATE FAULT ISOLATION AND VERIFICATION ROUTINES.
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1. ANY MEASURED PARAMETER.
2. PRE-STORED TESTS.
3. PRESENT STATUS OF STIMULI.
4. STORED LIMITS OR CONSTANTS.
5. ANY STORED DATA.
6. TEST RESULTS.
7. STATUS OF EMERGENCY INPUTS.

During normal testing, however, the Display System will be locked out and prevented from generating commands. The Display Unit to be used has not been defined at this time.

Flight PCM Unit (General)

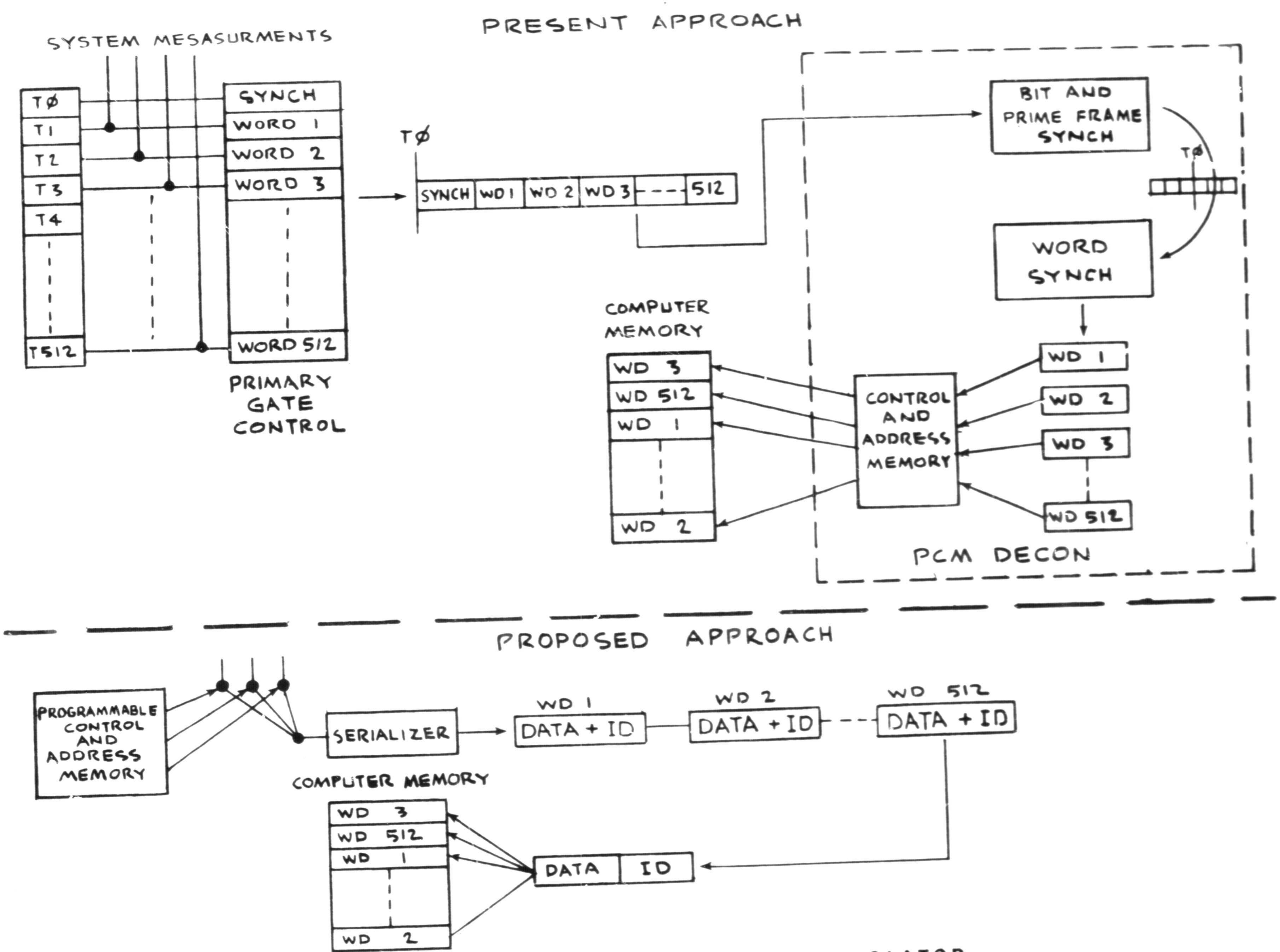
An interface to extract selected Data from the A/B PCM data stream will be provided. Basically, it will allow the Remote Computer to stay in sync with the A/B data stream and extract only those words it is interested in. This alleviates the memory storage problem of the 1824 Computer.

160G Translator

The checkout PCM stream, normally interleaved and sent to the Decom, will now be transmitted on separate link to a 160G Translator. The translator receives the 1 MB signal, performs certain checks and then generates a unit cycle directly into memory. Words 1, 641, etc. up to word 32,000 are special ID words, containing the PF count. Thus, there are 50 prime frames of 640 words each.

The incoming message is composed of 25 bits. Eight of these are data bits, 12 address, two parity and three coded error bits. The 25 bit word is first gated into a holding register. A check is then made to determine that valid data is available. Next the two parity bits and the 12-bit address is checked to ensure against transmission errors. If all is in order at this point, processing will begin. Alternate prime frames of data, odd and even, as determined by the prime frame count, will be loaded into separate sections of memory. In addition, the words are packed by sample rates, i.e., all the 50 s/s in sequence, 60 s/s, and so on. This is accomplished by using the 12-bit address portion of the incoming 25-bit data word, as a location in memory. In addition, 3 of the incoming bits are coded to represent 1 of 8 condition, as shown:

B_3	B_2	B_1	
0	0	0	- Good Word
0	0	1	- Not Out of Tolerance Floating and Out of Tolerance Fixed, Low
0	1	0	- No Data were available
0	1	1	- Not Out of Tolerance Floating and Out of Tolerance Fixed, High
1	0	0	- Out of Tolerance Floating and not Out of Tolerance Fixed
1	0	1	- Out of Tolerance Floating and Out of Tolerance Fixed, Low
1	1	0	- Prime Frame Count
1	1	1	- Out of Tolerance Floating and Out of Tolerance Fixed, High



SERIAL & PARALLEL CONVERTER AND TRANSLATOR

These three bits, plus the data will be written into the computer memory. This cycle will occur every 31.25 msec. It is hoped that this approach will alleviate many of the present Decom problems, previously described, and in particular, the loss-of-sync problem.

SOFTWARE AND 1824

The Remote System software performs, remotely, closed-loop checkout of the Ground Support Equipment and certain Command Module functions. The Remote System will supplement the functions currently performed by the ACE-S/C stations and interfaces with the existing ACE-S/C stations.

The Remote System software is composed of four functional areas: Executive, Control, Utility, and Test. These functional area programs are of necessity modular to allow for overlays in computer memory.

The Executive program consists of routines to control all functions of the Remote System. These routines control the handling of interrupts, analization of messages and transfer of control to the Control, Utility, or Test programs. The Executive, in addition to controlling closed loop tests, communicates with the central computer for manual input requirements such as starting and terminating tests and switching to the bypass mode of operation.

The Control programs consist of routines to control the stimulus equipment and the measurement equipment. The control of the stimulus and measurement equipment will be determined from pre-determined test sequences, from special routines, and from special test sequences transmitted from the central computer. While in the fault mode Control routines are used to access measurements and perform limit checks. Control routines are used to access separate A/B PCM measurements and perform limit checks and other analysis on that data. During the normal mode of operation, measurements other than A/B PCM are transmitted to the remote computer only when an out-of-limits condition exists. Some Control programs are classified as safing routines. These safing routines are used when critical measurements are encountered.

The Test programs consist of routines to simulate or create input data to the Executive, Control, and Utility programs for checking the program logic. Test programs also include routines to check out the stimulus and measurement equipment to insure that the equipment is operational.

The Utility programs consist of routines to perform conversions of data to engineering units, to transmit data to and from the central computer, to load the sequencer memory and verify the load, and to control data transfers with the remote computer console. Utility routines are used to build software program tapes and to allow for tape (data and system) file maintenance. Utility programs include two assemblers, one to generate sequencer programs and one to generate remote computer programs.

REMOTE SYSTEM

EXECUTIVE AREA	TIMING ROUTINE	MESSAGE ANALIZATION ROUTINE		
	INTERRUPT ROUTINE	MONITOR CONTROL ROUTINE		
CONTROL AREA	STIMULUS GENERATING ROUTINE	FAULT MODE ROUTINE	CRITICAL MEASUREMENT SAFING ROUTINE	
	MEASUREMENT ROUTINE	A/B PCM MEASUREMENT ROUTINE	TEST SEQUENCE ITEM ADVANCE ROUTINE	
UTILITY AREA	ENGINEERING UNIT CONVERSIONS ROUTINE	SEQUENCER LOAD AND VERIFY ROUTINE	CONSOLE COMMUNICATION ROUTINE	TAPE FILE MAINTENANCE ROUTINE
	COMPUTER TO COMPUTER TRANSFER ROUTINE	SEQUENCER PROGRAM GENERATION ROUTINE	SOFTWARE TAPE PREPARATION ROUTINE	FAULT MODE LIMIT CHECK ROUTINE
TEST AREA	EXECUTIVE SIMULATION ROUTINE	UTILITY SIMULATION ROUTINE	MEASUREMENT SIMULATION ROUTINE	
	CONTROL SIMULATION ROUTINE	STIMULUS SIMULATION ROUTINE		

GLOSSARY

CSM/LM	-	Command Service Module/Lunar Module
S/C	-	Spacecraft
CDC	-	Control Data Corporation
PCM	-	Pulse Code Modulation
A/N	-	Alpha Numeric
GSE	-	Ground Support Equipment
C/O	-	Carry-on
I/O	-	Input/Output
CDT	-	Compressed Data Tape
SPS	-	Samples per Second
G/N	-	Guidance/Navigation
C/O	-	Checkout
OCP	-	Operational Checkout Procedure